Coastal Services Center
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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STATEMENT OF WORK

Coastal Georgia Lidar

October 2009

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List of Acronyms

ASPRS ..... American Society of Photogrammetry and Remote Sensing
CO ..... Contracting Officer
COR ..... Contracting Officer's Representative
CRS ..... Coastal Remote Sensing
CSC ..... Coastal Services Center
DEM ..... Digital Elevation Model
DTM ..... Digital Terrain Model
FGDC ..... Federal Geographic Data Committee
LIDAR ..... Light Detection and Ranging
NAD ..... North American Datum
NAVD ..... North American Vertical Datum
NOAA ..... National Oceanic and Atmospheric Administration
NSSDA ..... National Standard for Spatial Data Accuracy
QA ..... Quality Assurance
QC ..... Quality Control
RMSE ..... Root Mean Square Error
SOW ..... Statement of Work

1 Overview

This Statement of Work (SOW) has been developed by the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center (referred to as the Center) to collect and deliver topographic elevation point data derived from multiple return light detection and ranging (lidar) measurements for areas in Coastal Georgia. Data are intended for use in coastal management decision making, including applications such as sea level rise and coastal flood mapping.

2 Background

The mission of the Center is to support the environmental, social, and economic well being of the coast by linking people, information, and technology. The Center is working with the Coastal Georgia Elevation Project (GCEP), led by the Coastal Regional Commission to acquire elevation data for the coastal counties of Georgia.

3 Requirements

The Contractor shall provide topographic elevation data for the designated areas of Figure 1 as described in this SOW. Data collection, processing, accuracy assessment, and delivery shall be accomplished in accordance with the following specifications. The contractor shall provide all necessary labor, equipment, material, software, and supplies to satisfactorily complete the SOW.

3.1 Data Coverage

The project area shall be as shown in Figure 1 below. The project area with a buffer of 3km (for potential errors), is estimated to cover approximately 2180 mi^2, but should be verified by the contractor. It is anticipated that the contractor shall acquire and process this data in conjunction with the Georgia Department of Natural Resources elevation project but for accounting purposes this project must also be kept separately. An ESRI shapefile of the project will be provided upon request.

3.2 Data Collection and Delivery

- The Contractor shall deliver the Lidar multiple-return points for the specified area(s) in the LAS 1.2 data format. All returns shall be delivered (including vegetation, buildings, etc) with the exception of obvious error points. The LAS file public header block shall include all required fields according to the September 2008 LAS1.2 specification. The LAS file shall also include the mandatory GeoKey DirectoryTag variable length header. The Point Data Record Format 1 shall be used and the intensity field shall be required. At a minimum, returns shall be classified for ground (2), for features such as bridges, vegetation, and structures as unclassified (1), water (9), low points (7), and overlap points (12) according to the American Society of Photogrammetry and Remote Sensing (ASPRS) LAS format classification table. Additionally, ground (2) points falling within areas defined as water for hydro enforcement shall be classified as 10. The Point Source ID field must be filled out for each record matching an ESRI geodatabase vector format file of the flightlines. The start and stop date/times for each flightline will also be included in the geodatabase. Each point in the LAS file shall also include the return number, number of returns from the pulse, time, and scan angle. Time is preferred in POSIX time format.
- Nominal point spacing for the Lidar mass points shall be 1 meter.
- Acquisition shall be +/- 2 hours of low tide.
- The LAS points shall be tiled into 5000 feet by 5000 feet tiles on even boundaries for State Plane Georgia East. Naming convention shall be specified by partners.
- The Contractor shall collect and deliver all point data referenced to the North American Datum of 1983 (NAD83) and the Geodetic Reference System of 1980 (GRS80). Horizontal units shall be in feet (State Plane Georgia East). Vertical units shall be in orthometric NAVD88 feet using the latest GEOID model (currently GEOID03).
- A bare-earth gridded hydro-enforced DEM shall be created and shall meet or exceed FEMA flood plain mapping specifications. Vertical datum for the gridded product shall be the North American Vertical Datum of 1988 (NAVD88) and horizontal datum shall be NAD83. The data shall be projected to State Plane Georgia East in ESRI grid format. Grid spacing shall be 4 feet. Vertical units shall be feet.
- Hydro breaklines are to be generated and provided in the same projection and datum as the DEMs. Hydro breaklines will be delivered in ESRI geodatabase format. See Attachment A.
- Base stations for GPS surveys shall be based on first or second order survey control stations that are part of the National Geodetic Survey's Spatial Reference System. In the event no suitable control is available, new control stations will have to be established using NGS-58 Guidelines for Establishing GPS- Derived Ellipsoidal Heights (Standards: 2 cm and 5 cm). New control stations will be sufficiently monumented to hold their position.

- Lidar data accuracy determination shall employ the National Standard for Spatial Data Accuracy (NSSDA). When compared to GPS survey grade points in generally flat non-vegetated areas, at least 95% of the positions shall have an error less than or equal to 1.2 feet (equivalent to root mean square error of 0.6 feet if errors were normally distributed). Horizontal accuracy shall be 4 feet RMSE or better. Additionally, the Consolidated Vertical Accuracy (computed using NDEP and ASPRS methodology in five (5) separate land cover classes (TBD)) shall meet ASPRS Class1 (or National Map Accuracy Standard) guidelines for the generation of 2 foot contours.
- Lidar data from different flight lines shall be consistent across flight lines, *i.e.*, there is minimal vertical offset within the noise level of the LiDAR system between adjacent flightlines. Maximum vertical offset between flightlines should be no more than 5 cm.
- Spatial coverage prior to vegetation editing shall be continuous in the designated geographic areas. Lidar data gaps between adjacent flight lines larger than two meters will not be acceptable. Overlap points will be supplied, but classified as 'overlap points' and removed from bare earth DEM.
- Two copies of the data shall be delivered by separate removable hard drives supporting USB 2.0 standards. The hard drive(s) will not be returned by the government.
- The Contractor shall deliver the x,y,z (latitude, longitude, elevation) data from the checkpoints used for quality control as well as the control points used to control the LiDAR flight missions. Points shall be delivered in ASCII format on the same media used for the elevation data delivery. The control and check points shall be delivered with sufficient detail regarding collection to allow the Government to tie into the same survey network of control points for an independent survey.
- Delivered elevation data shall become the property of the Government and will be shared with the public. The contractor shall retain the ability to use and distribute the data as they see fit.
- The contractor shall deliver a pilot area to the Government for review prior to final processing and delivery of final elevation data. Size TBD by contractor

If the contractor believes other delivery formats and/or mechanisms will serve the government's needs in a more efficient manner, the contractor is encouraged to propose alternatives.

3.3 Classification system

The contractor shall use the point classification system endorsed by the ASPRS for the LAS format. Ground shall be assigned a classification value of two (2), water shall be nine (9), and points that were examined but not classified as one of the ASPRS classes shall have a class value of one (1). Additional class

values for low points and overlap points will also come from ASPRS. Class 10 shall be used to denote bare ground points falling within water bodies.

3.4 Records and Metadata

The contractor shall document all delivered data and data products (including options if exercised) according to Executive Order 12906 (http://www.fgdc.gov/policyandplanning/executive_order/) for the whole of the project in one metadata product. Specifically, the contractor shall deliver for all data and data products, metadata records which detail all flight lines, flight dates and times, datums, reprojections, resampling algorithms, processing steps, field records, and any other pertinent information. The metadata records shall conform to the Content Standards for Digital Geospatial Metadata (FGDC-STD-001-1998) as published on May 1, 2000, by the Federal Geographic Data Committee (FGDC) or to any format that supersedes it as determined by the FGDC (http://www.fgdc.gov/metadata/csdgm/). Profiles and extensions to the standard that have been endorsed by the FGDC shall be used if they are applicable to the data or data products. The metadata records shall contain any and all elements, including those that are considered optional, wherever applicable to the data or data product. The metadata record shall contain sufficient detail to ensure the data or data product can be fully understood for future use and for posterity. The metadata records shall be delivered free of errors in both content and format as determined by the metadata parser (mp) program developed by the United States Geological Survey or an equivalent. The metadata records will be subject to review and approval prior to final acceptance by the Government.

3.5 Kickoff Meetings

The contractor shall participate in a kickoff meeting with the NOAA Coastal Services Center, GA Coastal Regional Commission, and other CGEP members within 30 days of contract award unless otherwise agreed upon by NOAA and the contractor. The contractor shall prepare an agenda for this meeting and issue meeting minutes within 7 days after the meeting.

3.6 Contractor Coordination

Communication and coordination between both the contractor and the Government is considered vital to the satisfactory accomplishment of this SOW. The Contractor shall expect periodic interaction with the Government to ensure clear understanding of the anticipated products and satisfactory progress in the delivery of products.

The contractor shall submit monthly progress reports to the Government summarizing progress made and problems encountered. After submittal of each of these reports the contractor shall schedule a conference call with the government to discuss the progress of the project and any issues that need to be addressed. The contractor shall prepare and distribute an agenda for the call

and shall distribute the meeting minutes within 5 days of the conclusion of the call.

3.7 Deliverables

This section contains the complete list of deliverables associated with this project. All submitted plans shall be of sufficient detail so that the Government can verify that the contractor has a thorough understanding of the requirements of this SOW. The contractor shall also complete the attached spreadsheet with a percentage of the overall task order that each deliverable represents and the proposed due date for each deliverable. This data will be used to track performance and for approval of invoices. The contractor may propose additional deliverables/ milestones in their technical proposal if they determine they are required. All deliverables including, monthly reports, shall be submitted using CSC's Task Order Management and Information System (TOMIS). The following project deliverables are required.

1 Work Plan – in some instances, the technical proposal may be accepted as the work plan. The work plan should include but is not limited to; potential base station locations, horizontal and vertical accuracy of the base stations, projected maximum baseline length for airborne trajectories, prior calibration reports, process to perform daily calibration checks, flight acquisition etc. The plan shall be in Microsoft Word format and **shall** include the major milestones and deliverables shown in **Gantt chart format**.
2 Flight path map and plan of LiDAR collecting aircraft.
3 Quality Control Plan – including detailed discussion of accuracy assessment methods/plan or other means of proving contract specifications have been met in Microsoft Word format.
4 Project schedule to include dates for all deliverables
5 Monthly progress report in a Microsoft Word, Excel or Project format on the 7th day of the month. In some cases a more appropriate regularly scheduled reporting timetable may be substituted contingent on agreement by all parties.
6 Final Report – The report shall summarize the project and provide the quality control evaluation showing that the project deliverables meet the contract specifications. The report shall be in Microsoft Word format.
7 FGDC-compliant metadata for all data sets per the project requirements
8 Pilot area of at least 5 tiles including points, DEMs, and hydro breaklines.
9 Digital elevation data sets per the requirements of section 3.2. These include:
   - Multiple-return classified mass point data in LAS format with nominal 1 meter spacing.
   - Bare-earth DEM. The DEM shall be in ESRI grid format and represent a continuous surface on land (no holes).
   - Hydro Breaklines
   - QA/QC validation data
   - Flightlines, as-flown, in ESRI geodatabase vector format, include start and

stop date/times for each flightline
- Ground control point locations, with epoch information, in ESRI geodatabase vector format

3.8 Product Delivery Schedule Guidance

The contractor shall propose a product delivery schedule in their technical proposal. As a guideline, the government does not expect delivery to require more than six-months from time of leaf off acquisition.

3.9 Product Delivery Addresses

The deliverables listed above shall be delivered to the COR at the following address. Technical questions shall be addressed to the Technical POC.

NOAA COR
NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, SC 29405
Attn: Dennis Hall
(843) 740-1323
Dennis.Hall@noaa.gov

NOAA Technical POC
NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, SC 29405
Attn: Keil Schmid
(843) 202-2620
Keil.Schmid@noaa.gov

4 Figures and Maps

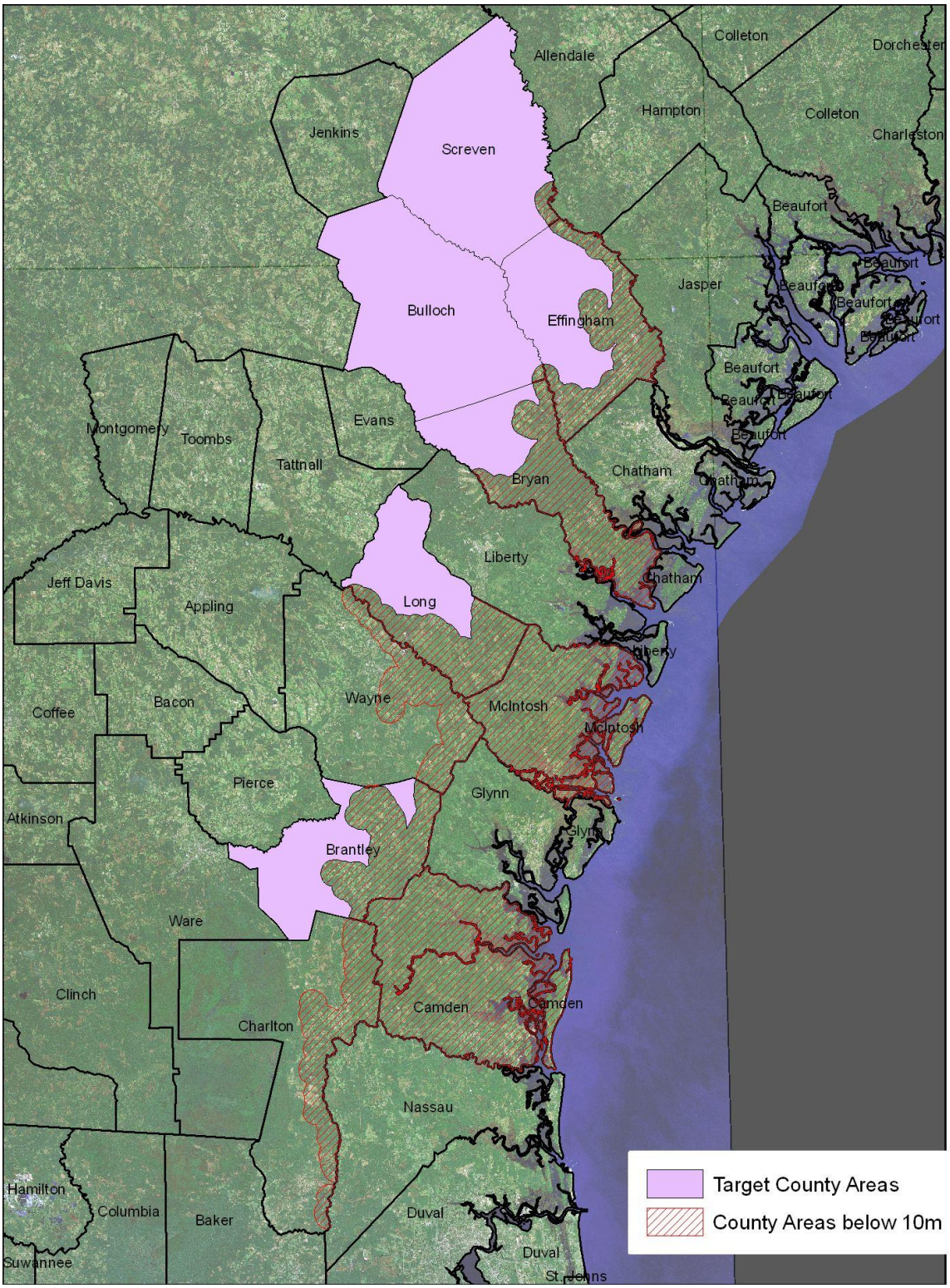


Figure 1. Target areas for LiDAR collection

Attachment A
Generation of a Hydrologically-Corrected Stream Network To Support Floodplain Mapping

A hydrologically-corrected stream network shall be generated such that all hydrologic feature components exhibit a downhill direction of flow, and that they are topologically structured (clipped, joined, and noded) at all line intersections, to maintain connectivity of the stream network. At a minimum, the following hydrologic features will be collected:

- Stream and canal centerlines
- Drainage ditches
- Tops and bottoms of stream banks
- Closed water bodies (lakes and ponds) having a surface area measuring greater than ¼ acre.

Development Rules: The following rules will apply to developing the hydrologically-corrected stream network:

1. Centerlines shall be generated for all streams, canals and ditches that drain an area greater than one square mile.
2. Centerlines shall remain unbroken through closed water bodies (lakes and ponds). ***See Example No. 1***
3. Centerlines shall remain unbroken where it is clearly evident where they meet road or railroad edges and pass through culverts or under bridges to the opposite side. ***See Example No. 2***
4. Streams having a width greater than 25feet for a distance greater than 0.5 miles shall be captured as a centerline with a double line stream channel that forms a closed polygon where the stream narrows or joins another stream channel polygon at a confluence. Streams having a width less than 25 feet shall be captured as a centerline with a single line stream channel.
5. All streamlines that are initially captured in 2D shall undergo a process that will assign elevations to the vertices of the centerline based on the surrounding lidar-derived bare earth points.
6. All streamlines regardless of capture method shall be hydro-enforced to ensure smooth continuous downhill flow. ***See Example No. 3***
7. Unique attribution shall be applied to single line streams, double line streams, so they are easily distinguishable from one another.

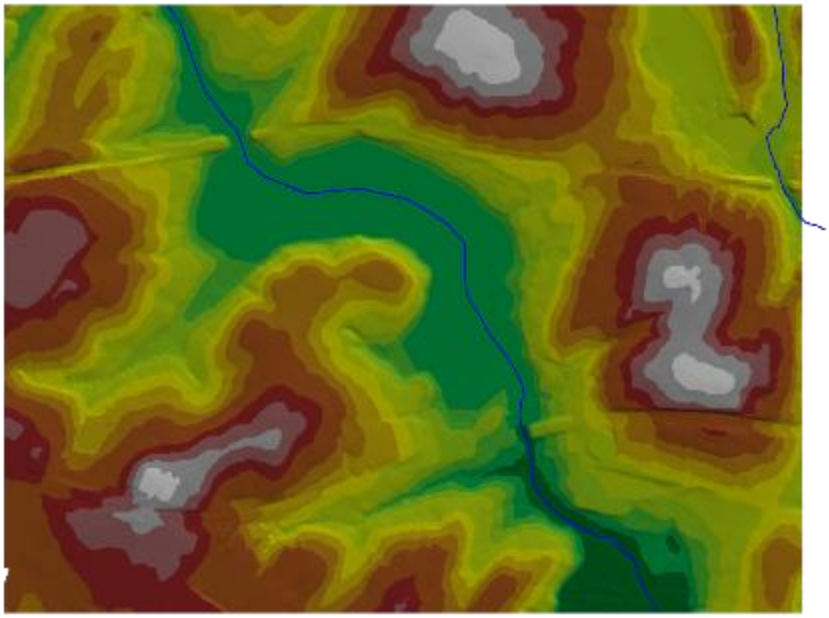
Other Lidar Data Requirements

- **Obscured Areas:** Heavily vegetated areas such as dense forested areas, mangroves, palmetto scrub, where the lidar bare earth point spacing is too sparse to accurately model the terrain surface, shall be delineated by "obscured area" polygons.

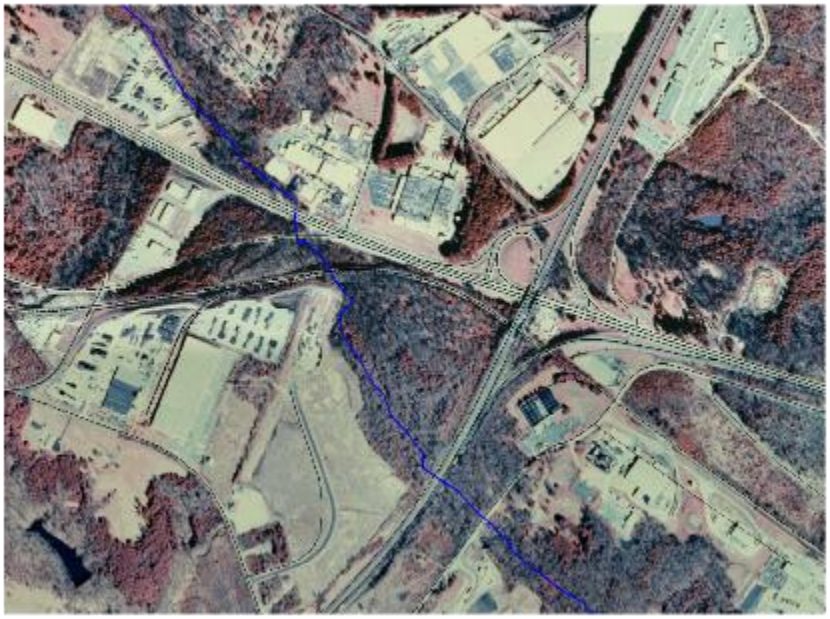
- **Data Cleanliness:** It is strongly recommended that the lidar data be processed to a true bare earth surface, by removing all above ground points. To facilitate the hydraulic modeling of riverine study areas, it is important to remove all bridges and large box culverts from the bare earth data set. Bridge and culvert points should be given a unique classification in the .LAS file.

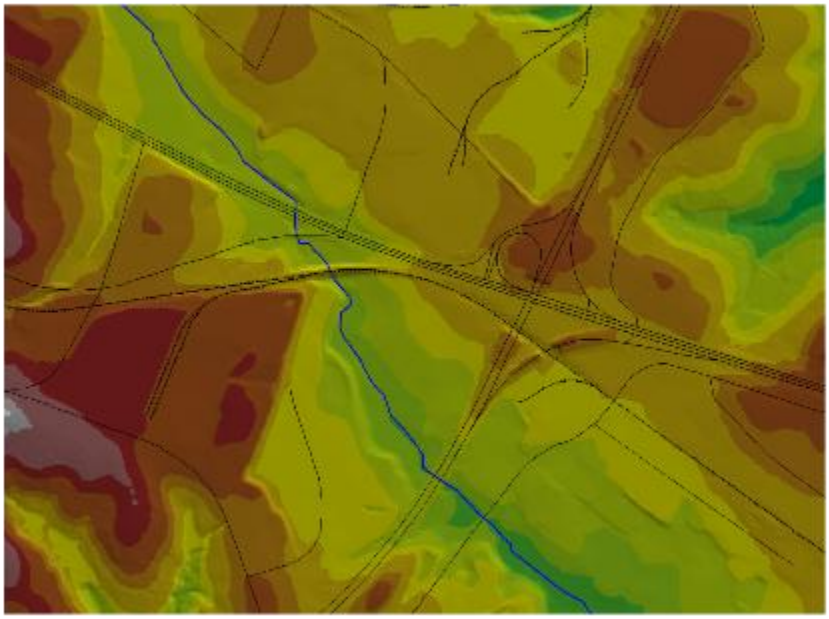
- **Water Points:**3D Polygons should be captured for all closed water body greater that ¼ acre in size as described above, **ALL** bare earth points falling within the water-body (i.e. mud flats, oyster reefs) should be reclassified as class 10 in the all-points lidar deliverable; they should be removed from the bare earth DEM.

Example No. 1
Continuous path lines through closed water bodies

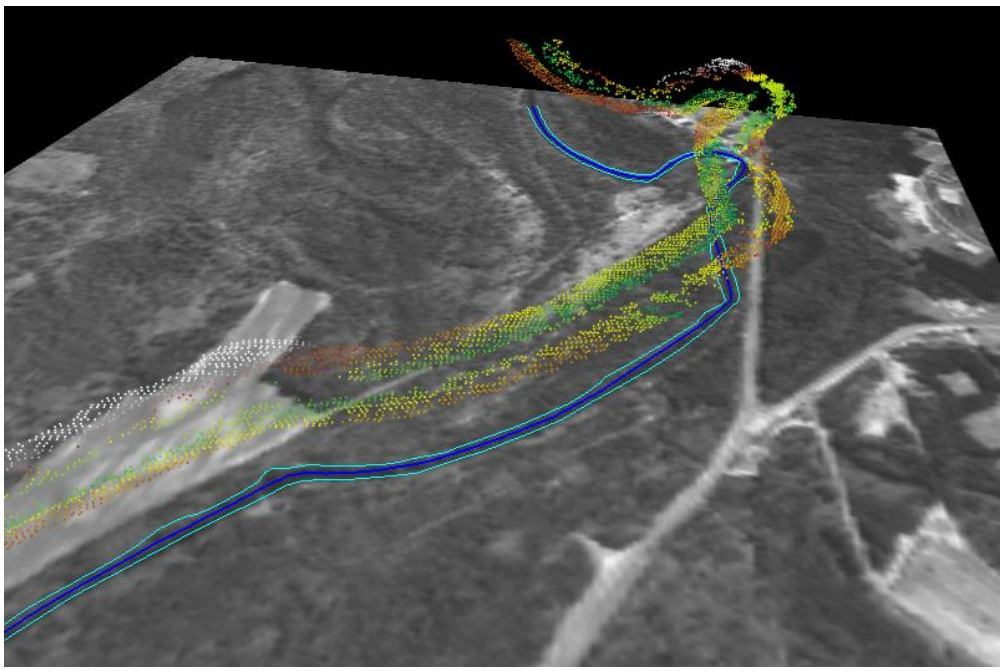


Example No. 2
Continuous path lines under roads and railroads

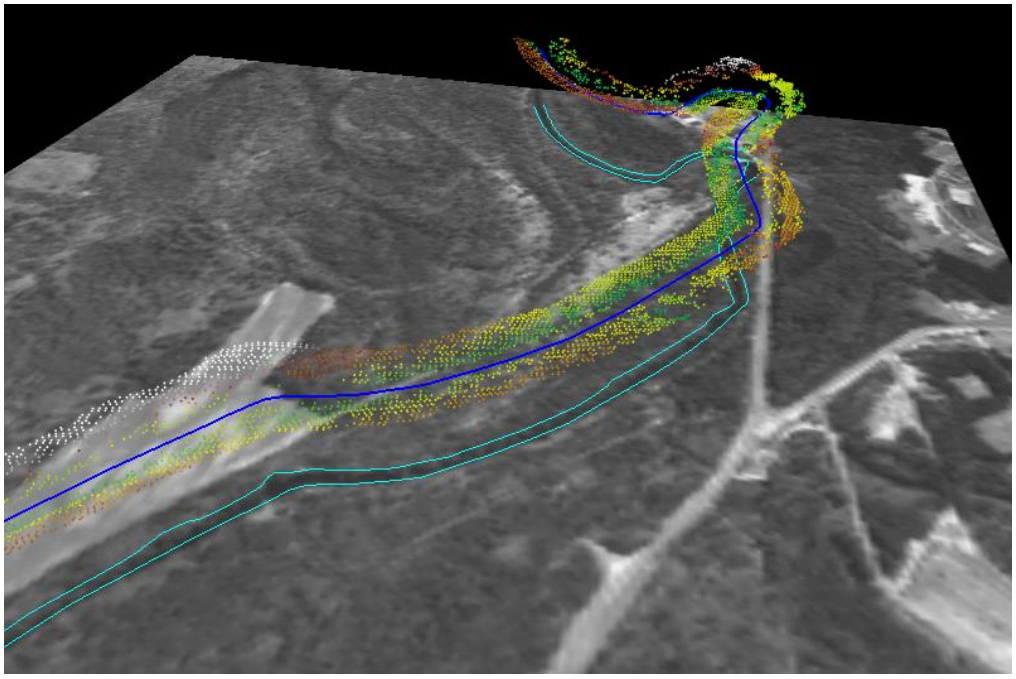




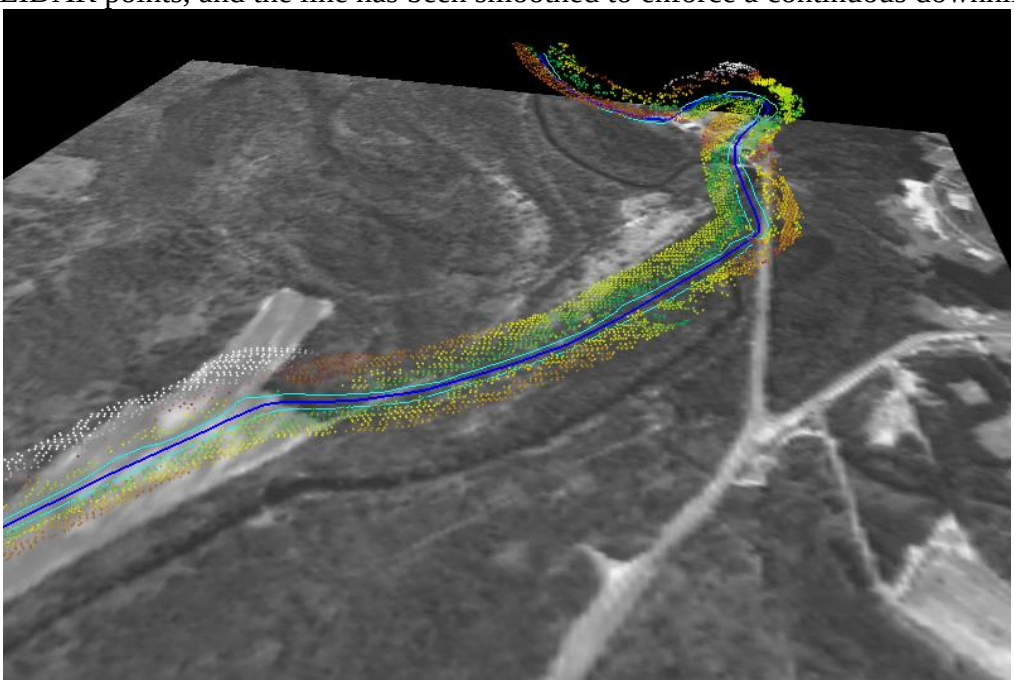
Example No. 3
Hydro-enforced 3D Breaklines



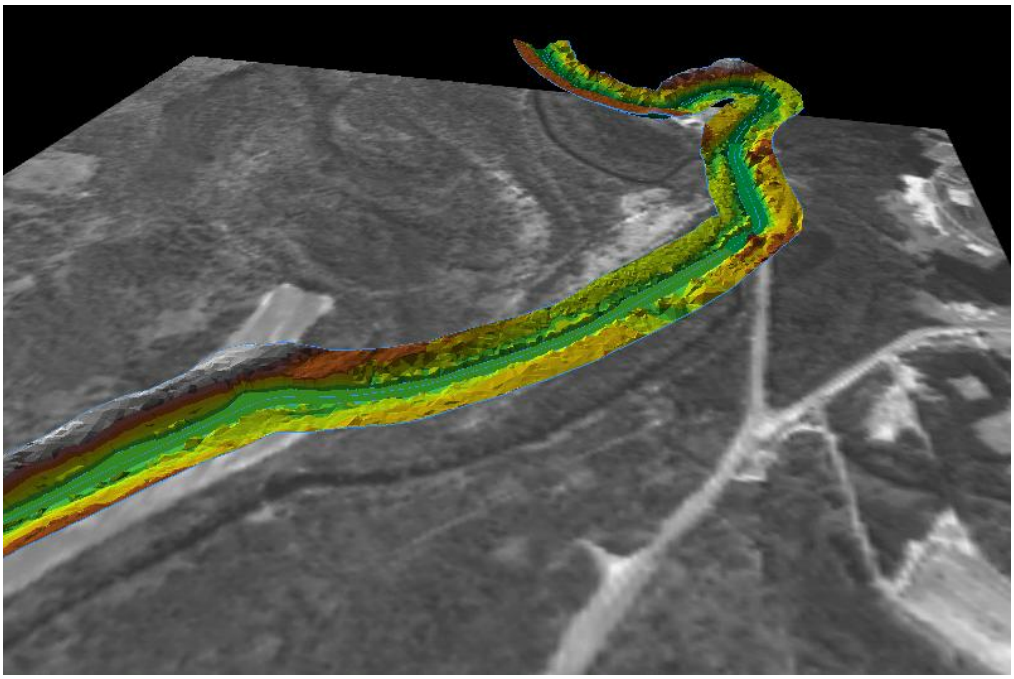
This shows the LIDAR Points at their true elevations above the orthophoto and new line work at 0 elevation



At this step, the vertices of the stream centerline have been assigned elevations from the LIDAR points, and the line has been smoothed to enforce a continuous downhill flow.



The vertices of the Edge-of-Bank lines are then adjusted vertically to match the stream centerline vertices.



A new TIN is then created from the remaining LIDAR points and the newly synthesized breaklines. This TIN shows the stream channel clearly defined at a level below the adjacent land.